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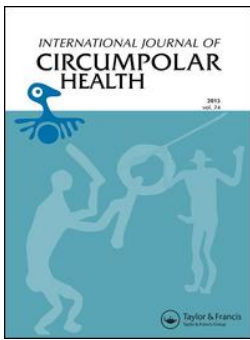
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Coverage rates of the children vaccination programme in Greenland

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ABSTRACT

In order to estimate the current coverage rate among all children in Greenland, we conducted an observational cross-sectional study identifying all children in Greenland eligible for a vaccination between 1 March 2018 and 16 June 2019. We found an overall national coverage of 85.4%. The national coverage for the vaccinations given at birth was 97.1%, dropping to 94.3%, 87.7% and 83.6% at ages 3, 5 and 12 months. Among children eligible for the Measles, Mumps and Rubella-vaccinations, the national coverage was 76.9% for children aged 15 months and 64.1% for children aged 4 years, but dropping to 40.9% in the districts. At preschool, the national coverage was 79.9%. Among the 12-year-old, the national coverages of the two vaccinations against Human Papilloma Virus were 88.4% and 71.6%, respectively, and for the three Hepatitis B-vaccinations 89.8%, 84.1% and 69.6%. A subgroup-analysis and test of an SMS-reminder system in Nuuk improved the coverage from 57.8% to 75.5% locally. Overall, we found a high national coverage rate among the newborn in Greenland. The national coverage rates of the remaining vaccinations were below the WHO-recommendations, however with great regional differences.

Abbreviations: CVP: Children Vaccination Programme; BCG: Bacille Calmette–Guerin; EMR: Electronic medical Record system; DTPHiB: Diphtheria, Tetanus, Pertussis, Polio, Haemophilus influenza B; HBV: Hepatitis B; HPV: Human Papilloma Virus; MMR: Measles, Mumps, Rubella; SMS: Short Text Message; WHO: World Health Organization; GVAP: Global Vaccine Action Plan; EVAP: The WHO European Vaccine Action Plan.

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In the previous years, Europe has seen 160,000 cases of measles and over 100 deaths related to this highly infectious disease [1]. This includes outbreaks of measles in places close to Greenland, such as Denmark and the Inuit-area of Inuvik in Northern America [2,3].

The vaccination against measles is included in the Children Vaccination Programme (CVP) throughout Europe, including Greenland. According to the World Health Organisation (WHO), a vaccination coverage rate of at least 95% is needed in order to prevent outbreaks and eliminate this disease [1].

Recently, studies of coverage rates among children in two larger towns in Greenland, Nuuk, the capital and Ilulissat, the third-largest town, have revealed suboptimal vaccination rates among children. In 2016, a study of the vaccination rates among children in Nuuk was made based on data extraction from a new electronic medical record system (EMR), which was introduced in March 2015 and includes a registration module for vaccinations. This study showed relatively high vaccination rates among children

younger than 12 months (80–99%), but rates as low as 55% and 34% for the first and second vaccination against measles, mumps and rubella (MMR) among preschool-children [4]. Another study from 2016 found that in the towns of Nuuk and Ilulissat, the total adherence to the vaccination programme among children up to the age of 10 years was 40%. Fifty-five per cent had incomplete adherence and 5% did not follow the programme at all [5].

However, the current coverage rate of the CVP among children in all of Greenland is unknown. A former study performed in 2004 based on the number of vaccinations reported to the chief medical officer compared to the number of children in Greenland estimated “reasonably well coverage” among children younger than 2 years, but with variation among the healthcare districts in Greenland [6]. Another study from 2003 reported high coverage rates among children younger than 2 years in the town Sisimiut but dropping rates among the older children [7].

The EMR introduced in Nuuk in 2015 was implemented in all hospitals and healthcare centres in Greenland

between November 2016 and July 2017, except the town Taasilaq in east Greenland. This makes it possible to estimate the national coverage rates based on data-extraction. This is highly relevant in order to prevent the spreading of preventable infectious diseases among children in general and among adults and children with immune-diseases.

Thus, the objective of this study was to estimate the current vaccination rates among children in all of Greenland.

Materials and method

The study was designed as an observational cross-sectional study based on statistical extractions and review of medical records.

Setting

Greenland is the largest island in the world covering approximately two million square kilometres. It is sparsely populated with a total of 56,000 inhabitants living in 17 towns and approximately 60 minor settlements. Twenty-four per cent of the population is children aged 16 years or younger [8]. The widespread population represents a real challenge to the national healthcare system in order to deliver high-quality healthcare, such as the CVP, to all inhabitants.

The healthcare system is divided into five healthcare regions: Avannaq, Disko, Qeqqa, Sermersooq and Kujataa (Figure 1). Each region consists of a number of towns and settlements. A regional healthcare centre is located in the largest town of the region while smaller local clinics exist in all other towns. Healthcare stations in settlements are the smallest healthcare units in Greenland [9].

The healthcare system in Greenland is a publicly financed healthcare system, meaning that preventive care, such as the vaccinations in the CVP, examinations and treatment are free for anyone with a permanent address in Greenland [10].

The CVP is based on the Danish programme with the addition of the Bacille Calmette–Guerin (BCG)-vaccination against tuberculosis and the vaccination-programme against Hepatitis B (HBV). The latter was introduced in 2010 and, as the first vaccination in this programme is administered at birth, children born before 2010 are offered three catch-up vaccinations when they are in a school-class corresponding to the age of 12 years [11–13].

The full programme and names and abbreviations of the diseases the vaccinations protect against can be found in Table 1.

A midwife administers the BCG- and HBV-vaccinations given at birth, except when the child is premature. Afterwards, the development and health of the child are monitored by a nurse, a doctor or the local health-worker until the child is approximately 12 months old. The health professional can remind and inform the parents of the vaccinations at ages 3, 5 and 12 months. When the child enters school, the vaccinations are offered to all children in specific school years. Currently, Greenland has no reminder-system for the vaccinations [13].

Study population

A statistical extraction identifying all children in Greenland eligible for a vaccination in the CVP between 1 March 2018 and 16 June 2019 was performed and their vaccination status registered.

The cohorts of children eligible for each of the vaccinations given before the age of 2 years were designed to include all vaccinations registered in the EMR-system unless the vaccination had been given with more than 1-month delay among the youngest in the cohorts.

The cohort of children eligible for the vaccination given at the age of 4 years was designed to include all vaccinations registered in the EMR unless the vaccination had been given with more than 4 months's delay.

For the vaccinations given at preschool and in schools at specific school years (children aged 5 to 6 years and 12 years), the cohorts were designed to include all children born in the year corresponding to the specific school year.

One month after the initial data extraction, a subgroup of children from Nuuk eligible for the first MMR-vaccination was reviewed manually. Short text messages (SMS) were sent to the parents of children appearing to have missed the vaccine, reminding them about the vaccine and informing them of the opening hours of the Queen Ingrid Health Care Center in Nuuk, where the vaccines in the CVP are administered. After 4 weeks, this group was reviewed again to assess the success of the SMS-reminder.

The ages of the children in each cohort can be seen in Table 1.

Data validation

The national EMR is directly linked to the national civil registry (CPR) in Greenland, meaning that every person with a permanent address in Greenland is automatically registered in the EMR. Synchronisation of data between the two systems is controlled by a built-in lookup function



Figure 1. The five healthcare regions of Greenland [33].

in the EMR to ensure that any recent changes to personal information are imported and stored correctly in the EMR. The consistency between the CPR and the EMR is validated every 24 h which is the maximum latency period for changes to the patients' personal information.

The extracted data was validated through manual revision of the EMR. A sub-sample of the extracted

data for 500 individuals was compared to their medical records to check for the degree of accordance between the extracted data and the EMR, including vaccination status, vaccination date, vaccination type and current address. The data extracted was found to be in complete accordance with the EMR.

Table 1. The Greenlandic child vaccination programme per 2019 and cohorts.

Recommended age at vaccination	Vaccination-type	Cohort born between	Age per 16 June 2019 (months)
0 weeks (at birth)	BCG: Tuberculosis	01.03.18–15.05.19	1–15
3 months	Hepatitis B (HBV)		
	Pneumococcal, Diphtheria, Tetanus, Whooping cough, Polio, Haemophilus influenza B (DiTePerPolHiB), HBV	01.12.17–15.02.19	4–18
5 months	Pneumococcal, DiTePerPolHiB, HBV	01.10.17–15.12.18	6–20
12 months	Pneumococcal, DiTePerPolHiB, HBV	01.03.17–15.05.18	13–27
15 months	Measles, Mumps, Rubella (MMR)	01.12.16–15.02.18	16–30
4 years	MMR	01.03.14–15.02.15	52–63
5–6 years (preschool)	DiTePerPolHiB	01.01.12–31.12.12	78–90
12 years + 0 months	Human Papillomavirus (HPV) (girls only)	01.01.06–31.12.06	150–162
	HBV ^a		
12 years + 2 months	HBV ^a	01.01.06–31.12.06	150–162
12 years + 6 months	HPV, HBV ^a	01.01.06–31.12.06	150–162
	Engerix-B-3		

^aChildren born before the vaccines administered at birth, 3 months, 5 months and 12 months were introduced, are offered three vaccinations when they are in a school-class corresponding to the age of 12 years.

Statistics

Data was extracted from the EMR between 5 July and 8 July 2019.

Group proportions were reported with percentages and compared using the Pearson Chi-Square test. A P-value of less than 0.05 was considered significant. Calculations were made in Microsoft Excel[®].

Ethics

The study was approved by the Ethics Committee for Medical Research in Greenland (study-ID: KVUG 2019–08) and the Agency for Health and Prevention in Greenland (29 May 2019).

The study was conducted in accordance with the Helsinki II-declaration.

Results

Total coverage rates

Total coverage rates can be found in Table 2.

Data-extraction showed that a total of 12,394 vaccinations should have been administered during the study period. Of these, 10,584 vaccinations were given, corresponding to an overall national coverage rate of 85.4%.

The lowest total coverage rate was found in Sermersooq (79.6%, $p < 0.001$) when compared to Greenland as a whole and the highest was found in Disko (91.7%, $p < 0.001$).

Tuberculosis

The coverage rates of the BCG-vaccination can be found in Table 3.

We found a national coverage rate of 97.1% for the BCG-vaccination. The lowest coverage rate was found in

Table 2. Total coverage rates for all healthcare districts and Greenland as a total.

	Vaccinated	Not vaccinated	Total	Coverage Rate %
Avannaa	2,412	346	2,758	87.5**
Disko	1,466	133	1,599	91.7***
Kujataa	1,289	158	1,447	89.1***
Qeqqa	1,955	287	2,242	87.2*
Sermersooq	3,462	886	4,348	79.6***
Greenland	10,584	1,810	12,394	85.4

Asterisk symbol : significant higher or lower coverage rate when compared to Greenland as a whole.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Qeqqa at 92.4% ($p < 0.001$) and the highest in Avannaa at 99.1% ($p < 0.05$).

Hepatitis B

The national and regional coverage rates of the HBV-vaccinations can be found in Table 4.

The national coverage rate of the HBV-vaccination was highest at the time of birth (96.4%) with a drop to 94.4% at 3 months ($p < 0.05$) and further and significant drops to 88.4% at 5 months and 83.9% at 12 months ($p < 0.001$ and $p < 0.01$). Among the 12-year olds, the coverage was 89.8% with a significant drop to 84.4% at age 12 years and 2 months ($p < 0.001$) and to 69.6% at age 12 years and 6 months ($p < 0.001$). Regionally, for the vaccinations administered among the children born after 2010, the lowest coverage rate, 74.3%, was observed at 12 months in Sermersooq and the highest, 100%, at 3 months in Kujataa.

Diphtheria, Tetanus, Pertussis, Polio, Haemophilus influenza B (DTPHiB)

The coverage rates of the DTPHiB-vaccine can be found in Table 5.

Table 3. Coverage rates of BCG, MMR and vaccinations against HPV and pneumococcal disease.

	Tuberculosis	Pneumococcal disease			MMR		HPV	
	0 months BCG	3 months	5 months	12 months	15 months	4 years	12 years 0 months	12 years 6 months
Avannaa								
Vaccinated	215	196	161	148	159	141	69	54
Not vaccinated	2	22	36	36	21	20	5	20
Total	217	218	197	161,841	180	161	74	74
Coverage Rate %	99.1 [^]	89.9 ^{^^}	81.7 ^{^^*}	80.4	88.3 ^{^^^}	87.6 ^{^^^}	93.2	73.0 ^{**}
Disko								
Vaccinated	109	114	100	106	110	78	49	42
Not vaccinated	3	1	12	10	13	17	2	9
Total	112	115	112	116	123	95	61	51
Coverage Rate %	97.3 (ns)	99.1 [^]	89.3 ^{**}	91.4 [^]	89.4 ^{^^^}	82.1 ^{^^^}	96.1	82.4 [*]
Kujataa								
Vaccinated	108	108	111	105	101	69	28	14
Not vaccinated	1	0	3	8	15	6	6	20
Total	109	108	114	113	116	75	34	34
Coverage Rate %	99.1 (ns)	100 ^{^^}	97.4 ^{^^^}	92.9 ^{^^}	87.1 ^{^^}	92.0 ^{^^^}	82.4	41.2 ^{^^^***}
Qeqqa								
Vaccinated	159	154	148	159	145	58	49	46
Not vaccinated	13	7	11	13	25	59	9	12
Total	172	161	159	172	170	117	58	58
Coverage Rate %	92.4 ^{^^^}	95.7	93.1 [^]	92.4 ^{^^^}	85.3 ^{^^}	49.6 ^{^^^***}	84.5	79.3 [*]
Sermersooq								
Vaccinated	319	277	257	241	176	104	116	96
Not vaccinated	8	21	47	82	134	150	19	39
Total	327	298	304	323	310	254	135	135
Coverage Rate %	97.6 (ns)	93.0	84.5 ^{^^**}	74.6 ^{^^^**}	56.8 ^{^^^}	40.9 ^{^^^***}	85.9	71.1 ^{**}
Greenland								
Vaccinated	910	849	777	759	691	450	311	252
Not vaccinated	27	51	109	149	208	252	41	100
Total	937	900	886	908	899	702	352	352
Coverage Rate %	97.1	94.3	87.7 ^{***}	83.6 [*]	76.9	64.1 ^{***}	88.4	71.6 ^{***}

Asterisk symbol : significant decrease/increase in coverage rate when compared to previous vaccination in the same region.

*p < 0.05, ** p < 0.01, ***p < 0.001.

Cap symbol : significantly lower/higher coverage rate when compared to the rest of Greenland.

[^]: p < 0.05, ^{^^}: p < 0.01, ^{^^^}: p < 0.001.

The DTPHiB-vaccine is given in conjugation with the HBV-vaccine at age 3, 5 and 12 months and so the national and local coverages are the same as the HBV-vaccine at these ages.

Regarding the booster given at preschool at age five or 6 years, we found a national coverage of 79.9%. Sermersooq and Qeqqa both had significantly lower coverage rates when compared to the rest of Greenland at 70.4% and 71.9%, respectively (p < 0.001 and p < 0.05), and Avannaa and Disko both had significantly higher coverage rates at 93.5% and 92.7% (both p < 0.001).

Pneumococcal disease

All coverage rates for the vaccine against pneumococcal disease can be found in Table 3.

The national coverage of the vaccination against pneumococcal disease was 94.3% at 3 months, 87.7% at 5 months and 83.6% at 12 months. There were significant drops in the coverage rate between each vaccination (p < 0.001 and p < 0.05).

Regionally, the highest coverage rate was found in Kujataa at 100% at 3 months, and the lowest in Sermersooq at 74.6% at 12 months. Avannaa, Disko and Sermersooq had significant drops in coverage from 3 to 5 months and Sermersooq from 5 to 12 months.

Measles, Mumps and Rubella

All coverage rates for the MMR-vaccination can be seen in Table 3.

The national coverage of the first MMR-vaccination administered at 15 months was found to be 76.9% with a significant drop to 64.1% (p < 0.001) for the second vaccination at 5 years.

The lowest coverage rate for both vaccinations was found in Sermersooq at 56.8% and 40.9%, both significantly lower when compared to the rest of the country (both p < 0.001). The highest coverage rate for the first vaccination was found in Disko at 89.4% and for the second in Kujataa at 92.0% (both p < 0.001 when compared to the rest of the country).

Table 4. Coverage rates of HBV-vaccination.

	HBV						
	0 months	3 months	5 months	12 months	12 years 0 months	12 years 2 months	12 years 6 months
Avannaa							
Vaccinated	211	196	163	151	150	138	116
Not vaccinated	6	22	34	33	11	23	45
Total	217	218	197	184	161	161	161
Coverage Rate %	97.2	89.9 ^{^^^**}	82.7 ^{^^*}	82.1	93.2 ^{**}	85.7 [*]	72.0 ^{**}
Disko							
Vaccinated	107	114	102	106	84	84	72
Not vaccinated	5	1	10	10	7	7	19
Total	112	115	112	116	91	91	91
Coverage Rate %	95.5	99.1 ^{^*}	91.1 ^{**}	91.4 [^]	92.3	92.3 [^]	79.1 ^{^*}
Kujataa							
Vaccinated	106	108	111	106	65	59	34
Not vaccinated	3	0	3	7	11	17	42
Total	109	108	114	113	76	76	76
Coverage Rate %	97.2	100.0 ^{^^}	97.4 ^{^^}	93.8 ^{^^}	85.5	77.6	44.7 ^{^^^***}
Qeqqa							
Vaccinated	160	154	148	159	116	109	104
Not vaccinated	12	7	11	13	14	21	26
Total	172	161	159	172	130	130	130
Coverage Rate %	93.0	95.7	93.1 [^]	92.4 ^{^^^}	89.2	83.8	80.0 [^]
Sermersooq							
Vaccinated	319	278	259	240	230	214	174
Not vaccinated	8	20	45	83	30	46	86
Total	327	298	304	323	260	260	260
Coverage Rate %	97.6	93.3 [*]	85.2 ^{^^**}	74.3 ^{^^^***}	88.5 ^{***}	82.3 [*]	66.9 ^{***}
Greenland							
Vaccinated	903	850	783	762	645	604	500
Not vaccinated	34	50	103	146	73	114	218
Total	937	900	886	908	718	718	718
Coverage Rate %	96.4	94.4 [*]	88.4 ^{***}	83.9 ^{**}	89.8 ^{***}	84.1 ^{**}	69.6 ^{***}

Asterisk symbol : significant decrease/increase in coverage rate when compared to previous vaccination in the same region.

*p < 0.05, ** p < 0.01, *** p < 0.001.

Cap symbol : significantly lower/higher coverage rate when compared to the rest of Greenland.

^: p < 0.05, ^^: p < 0.01, ^^*: p < 0.001.

Sermersooq and Qeqqa both had significant drops in the coverage rate between the two vaccinations.

Human Papillomavirus (HPV)

The coverage rates of the HPV-vaccination can be found in Table 3.

We found the national coverage rate of the first HPV-vaccination to be 88.4%, with a significant drop to 71.6% at the second vaccination (p < 0.001).

There were no significant differences between the coverage rates of the first vaccination in any of the regions when compared to the rest of the country, but the coverage rate of the second vaccination was significantly lower in Kujataa (41.2%, p < 0.001).

Subgroup analysis of children in Nuuk regarding the first MMR-vaccination

A subgroup of 289 of children living in Nuuk eligible for the first MMR-vaccination was identified after the initial data-extraction. We found that in this group, 57.8% (167/289) had received the vaccination according to schedule.

A manual review 1 month later revealed that 3.8% (11/289) of the children had moved to Nuuk before the MMR-vaccination should have been administered, leaving their vaccination-status unknown and the true coverage rate 60.1% (167/278). Furthermore, additional 15 children had received the vaccination in the 1-month period after the first data-extraction, thereby increasing the vaccination rate to 65.5% (182/278). Among the remaining 96 children, an SMS was sent to the parents of 80 children with available telephone numbers. A final review performed 4 weeks after the SMS was sent, revealed that another 28 children had been vaccinated, increasing the coverage rate to 75.5% (210/278). Among children that had received all vaccines except the MMR, 44% (22/50) were vaccinated after the SMS-reminder compared to 20% (6/30) of the children were missing at least one other of the vaccines in the CVP.

Discussion

The overall national coverage rate of the CVP of 85.4% documented in this study is relatively high, indicating a general good public support and

Table 5. Coverage rates of DTPHiB-vaccinations.

	Diphtheria, Tetanus, Pertussis, Polio, Haemophilus Influenza B			
	3 months	5 months	12 months	Preschool
Avannaa				
Vaccinated	196	163	151	144
Not vaccinated	22	34	33	10
Total	218	197	184	154
Coverage Rate %	89.9 ^{^^^*}	82.7 ^{^^*}	82.1	93.5 ^{^^^*}
Disko				
Vaccinated	114	102	106	89
Not vaccinated	1	10	10	7
Total	115	112	116	96
Coverage Rate %	99.1 ^{^*}	91.1 ^{**}	91.4 [^]	92.7 ^{^^^}
Kujataa				
Vaccinated	108	111	106	56
Not vaccinated	0	3	7	16
Total	108	114	113	72
Coverage Rate %	100.0 ^{^^}	97.4 ^{^^}	93.8 ^{^^}	77.8 ^{**}
Qeqqa				
Vaccinated	154	148	159	87
Not vaccinated	7	11	13	34
Total	161	159	172	121
Coverage Rate %	95.7	93.1 [^]	92.4 ^{^^^}	71.9 ^{^^^*}
Sermersooq				
Vaccinated	278	259	240	162
Not vaccinated	20	45	83	68
Total	298	304	323	230
Coverage Rate %	93.3 [*]	85.2 ^{^^*}	74.3 ^{^^^*}	70.4 ^{^^^}
Greenland				
Vaccinated	850	783	762	538
Not vaccinated	50	103	146	135
Total	900	886	908	673
Coverage Rate %	94.4 [*]	88.4 ^{***}	83.9 ^{**}	79.9 [*]

Asterisk symbol : significant decrease/increase in coverage rate when compared to previous vaccination in the same region.

*p < 0.05, ** p < 0.01, *** p < 0.001

Cap symbol : significantly lower/higher coverage rate when compared to the rest of Greenland.

^: p < 0.05, ^^: p < 0.01, ^^*: p < 0.001.

adherence to the programme. However, a goal of at least 90% coverage rate of all vaccines in the CVP, as suggested by the WHO Global Vaccine Action Plan 2011–2020 (GVAP), has not been reached in Greenland [14].

The highest coverage rates were observed for vaccinations given at birth (97%), followed by vaccinations administered among children at or below 12 months (82–94%) and among school children (70–93%). The lowest rates were observed for the MMR-vaccinations at 15 months and 4 years, 77% and 64%, respectively. Even lower rates, below 60%, were observed in Sermersooq, indicating a pronounced need for improvement here when compared to the other regions.

The results for each of the vaccines in the Greenlandic CVP are discussed below.

Tuberculosis

Greenland is a high-endemic area for tuberculosis and in 2015 the incidence was 145 cases per 100,000 inhabitants

[15]. The BCG-vaccine has been part of the children vaccination programme since 1955 but was temporarily discontinued from 1991 to 1996 [16]. The BCG-vaccine protects against meningitis and disseminated tuberculosis in children [17] and Michelsen et al. found in a study in Greenland from 2014 that the vaccine also protects against mycobacterium tuberculosis-infection and tuberculosis-disease among Greenlanders [16].

We found high coverage rates in all regions, indicating that the current system with the vaccine being administered at birth is highly effective.

Hepatitis B

The screening of pregnant women for HBV was introduced in Greenland in 1992 and the vaccine became a part of the CVP in 2010. WHO recommends a national coverage of the HBV-vaccine of at least 90% in countries where the disease is endemic, such as Greenland [14]. In this study, we found that this goal was reached at birth and at 3 months.

In a study by Rex et al. [18], they found the coverage rates in 2012 to be 55% for the vaccine administered at birth and 38.5% for the fourth vaccine. In our study, we found that the national coverage rates have improved and more than doubled at 12 months since 2012, which could signify a gradual improvement since the implementation of the vaccine in the CVP.

According to the WHO, having all three vaccinations is essential in order to achieve at least 20 years, and possibly lifelong, immunity [19]. As HBV can cause liver diseases such as cirrhosis and hepatocellular carcinoma, a follow-up on the children in Greenland that have not completed the programme seems essential.

Diphtheria, Tetanus, Pertussis, Polio, Haemophilus influenza B

The WHO European Vaccine Action Plan (EVAP) aims towards a national coverage rate of at least 95% of three doses of a DTP-containing vaccine in 2020 in at least 90% of the member-countries and at least 90% coverage in at least 90% of the regions in all member-countries [20].

Nationally, Greenland reached a national coverage rate above 90% only at age 3 months. Locally, three of the regions reached coverage rates above 90% for the three first vaccinations, namely Disko, Kujataa and Qeqqa, while only Disko reached a coverage rate above 90% for all four. The Sermersooq-region only achieved a coverage of at least 90% this for the first vaccination given at 3 months and Avannaq only for the booster.

This means that only 60% of the Greenlandic regions reached the WHO-recommended goal of a 90% coverage of three doses of a DTP-containing vaccine.

In 2016, the coverage rates in Nuuk for the DTP-containing vaccines were 91.5% at 3 months, 80.2% at 5 months, 69.8% at 12 months and 68.3% for the booster [4]. The current coverage rates in Sermersooq of 93.3%, 85.2%, 74.3% and 70.4% could therefore indicate an improvement.

Pneumococcal disease

The incidence of respiratory infections caused by pneumococci is high among children in Greenland. In 2016 Kløvgaard et al. found that diseases of the respiratory system and diseases of the ear were among the most common causes of hospitalisation among children and otitis media one of the most common causes for outpatient consultations [5]. Previous studies have also found high incidences of invasive pneumococcal disease (IPD) among Inuit, such as meningitis [21].

We found a national coverage rate above the WHO-recommended 90% at 3 months but gradually dropping at 5 months and 12 months. Kujataa and Qeqqa had a coverage above 90% for all three vaccinations and Disko dropped below to 89.3% only at 5 months. Sermersooq had the lowest coverage rate, dropping as low as 74.6% at 12 months.

Measles, Mumps and Rubella

As measles is a highly infectious disease, WHO recommends a national coverage rate of at least 95% for two doses of measles-containing vaccine [22].

The coverage rates found in this study are not only below the WHO-goal but also the estimated world coverage of 87% for the first dose and 67% for the second. Comparing the data from this study with data from WHO from 2017, Greenland has a coverage rate comparable to that of India, Iraq, Syria and several sub-Saharan African countries [23,24].

The two regions with the lowest coverage rates are by far Sermersooq with 56.8% and 40.9% coverages for the two vaccinations and Qeqqa with a drop from 85.3% to 49.6% from the first to the second vaccination.

There have been no known cases of measles in Greenland but being closely connected to Denmark by air-traffic, there is a risk of measles spreading from the rest of Europe to Greenland. Denmark has had 15 cases of measles per 30 July 2019, almost a double of the number of cases in 2018 [25] and are also below the WHO-recommended coverage rate (94% for the first vaccination and 89% for the second) [26]. It seems

essential that improvements in the coverage of the MMR-vaccine become a focus point.

Human Papillomavirus

With an incidence of approximately nine cases per year per 100,000 inhabitants [27], Greenland has a high incidence of cervical cancer and a high mortality rate of the disease when compared to the rest of Europe [28]. Greenland has been following the screening programme for cervical cancer since 1998, but a study from 2016 found low screening coverage rates from 1998 to 2011, the highest being 54% in 2011 [29]. As HPV often is the cause of cervical cancer, this makes a high coverage of the vaccination against HPV essential.

Along with Denmark, Greenland was among the first Nordic countries to introduce the HPV-vaccination in 2009 [30], but the coverage rate of the vaccination in Greenland has been unknown until now.

We found high national coverage rates of HPV-vaccinations, however with regional differences. The national coverage rate in Greenland is higher than the current nation coverage rate in Denmark (73% for the first vaccination and 52% for the second) [26] and comparable to the coverage in other European countries, where the percentage of girls who receive the final dose of the vaccination ranges between 14.1% and 85.9% [31].

Improving vaccination coverage in Greenland

A focused effort is needed to improve the vaccination coverage rates in Greenland. As Greenland is a country with a challenging infrastructure and great differences between the healthcare offered in towns and settlements, multifaceted approaches will be needed, each tailored to the place they are to be implemented.

In this study, we found clear differences in coverage rate between the regions regarding certain vaccines and that Sermersooq, which holds the main hospital of the country and the country's largest healthcare-clinic, often had the lowest coverage rate. We also found that the coverage rates were highest among the newborn and then, with a few regional exceptions, dropping until the HBV-vaccination series started in school at age 12 years. This could indicate that the coverage is higher when the family has close contact with either the healthcare-system or a school which can provide education and reminders of the CVP.

Education and reminder-systems have proven effective in other countries. In a study from 2017 concerning the uptake of HPV-vaccinations among American Indian

adolescents, Jacobs-Wingo et al. found several barriers to the vaccination, the top five being lack of patient awareness about benefits, missing vaccination data, clinic access issues, vaccine safety concerns and parent beliefs that HPV-vaccination increases sexual activity. Researchers found that clinics expanding their reminder-systems, educating the staff and initiating or expanding patient-education and possibilities for having the vaccinations outside the clinic, improved the initiation of the HPV-vaccines from 47% to 71% and completion from 20% to 42% [32].

Following the annual assessment of the coverage rate of the children vaccination programme in Denmark in 2018, Statens Serum Institut conducted interviews with the regions having the highest coverage rates of the MMR-vaccination. These interviews showed that also in Denmark, regions focusing on education of parents, collaboration between general practitioners and nurses conducting home-visits among new parents and expansion of reminder-systems have the highest coverage rate [26].

One SMS reminder improved the vaccination rate among the subgroup in Nuuk missing the MMR-1 vaccine, in particular among children that were missing only this vaccine. Thus, SMS-reminders may be one way to improve vaccination rates. However, additional alternatives have to be considered to reach acceptable vaccination rates including repeated SMS-reminders, direct telephone contact with parents and follow-up on vaccination status among all children upon contact to the healthcare-system, at school entry and in day care intuitions.

Conclusion

We found an overall national coverage that is close to the WHO-recommendations and especially high among the newborn. However, great regional differences were observed. It is vital that the coverage rate is monitored closely in the future and a catch-up strategy for the children missing one or more vaccinations should be introduced along with other initiatives to improve coverage rate.

Strengths and limitations

This is the first study based on individual registration of vaccinations in the EMR focusing on the coverage rate of the CVP among children in all of Greenland and including all health regions. The coverage rates reported in this study should be interpreted as minimum rates, as the design of the cohorts may make the coverage rates appear lower than they actually are. Among the youngest, children born prematurely may receive the BCG- and HBV-vaccinations with some delay due to their immature immune system at birth. Among

the older children, the vaccinations given in school may have been given later than assumed in this study, if the child has entered school at an older age than expected.

The organisation of vaccination-schedules may differ among regions and especially the coverage rates of the vaccination against DTPHiB at age 5 to 6 years, the second against HPV and the third against HBV at age 12 years, may reflect planned delays in the vaccine programme rather than lack of adherence. Thus, these vaccination rates must be taken with clear reservations.

Children who have moved to Greenland from other countries may have been given the vaccinations before departing their home-country and may therefore appear in the EMR as not having received the vaccination, even if this is not the case. The analysis of the subgroup in Nuuk indicated that this underestimation may account for 3% to 4%.

The subgroup-analysis of the effect of SMS-reminders among children in Nuuk was conducted without a control group. Thus, these results must not be considered conclusive until they have been confirmed in more expansive studies.

Finally, there is a small possibility that some vaccinations could have been administered, but not registered in the EMR. However, when doing the data-validation of 500 children, we found no disagreements between the extracted data and the notes written by the healthcare staff in the EMR.

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